Decision Making and Information Technology

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Command and Control Systems Course
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Topics to Be Discussed

- Underlying Principles and Theory
  - How and Why Do We Make Decisions?
  - The Role of Information in the Process
  - Knowledge, Understanding, and Appreciation
  - The Implications of the Expanded Availability of Information
- Applying Modern Information Technology
  - The Long Term Vision of the Future Battlespace
  - Navigating Toward the Future Vision
  - Implementation: Building From the Present
  - Tools to Help the Warfighters
- Obstacles in the Path

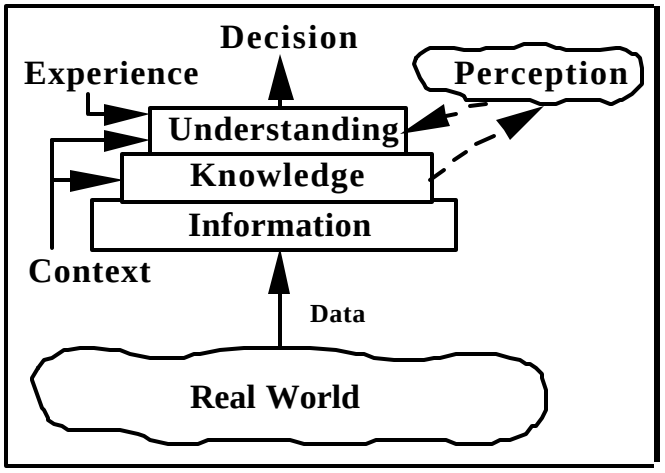
Three Types of Decision Drivers

- Procedure
  - Decisions That Are Made According to a Schedule
  - Examples: the Daily Briefing to the Boss, the ATO, Ordering Lunch
- Need
  - Event-driven
  - A Decision Must Be Made to Respond to the Event
  - Examples: Destroy Incoming Missile, Steer Car Around Pothole
- Opportunity
  - Event-driven
  - If a Decision Can Be Made Quickly Enough, Some Unanticipated Gain May Result
  - Example: Enemy CP Sighted, One-day Price Reduction

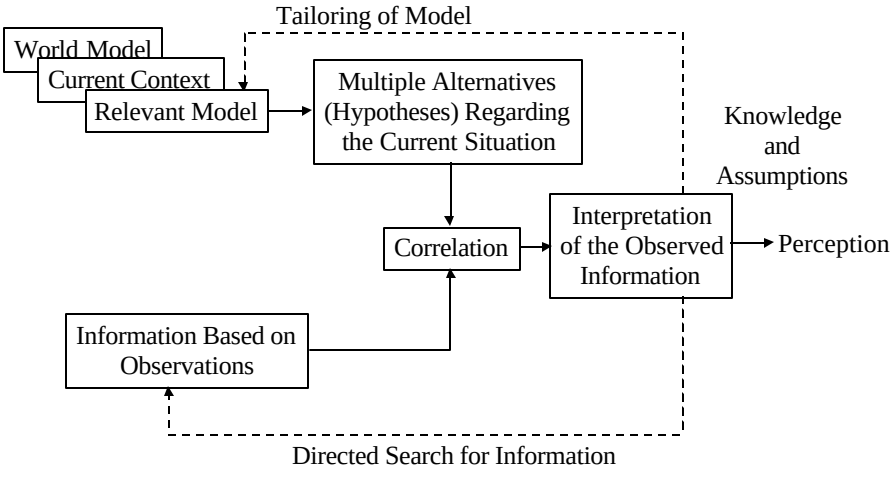
The Use of Information in Decision-making

- The More We Know About the Situation, the Better Is Our Ability to Make a Good Decision
  - Not Really True: the More We Understand, Not the More We Know
  - Too Much Information Can Be Worse Than Too Little
  - "Glare of War" Combined With "Fog of War" Can Be a Problem
- Decision-support Involves the Use of Information to Support Deliberate Action
  - The Most Important and Often Overlooked Aspect of Information System Design and Operation
  - If We Cannot Act on the Information, Why Bother With It?
  - Timeliness and Relevance Are Key to Success

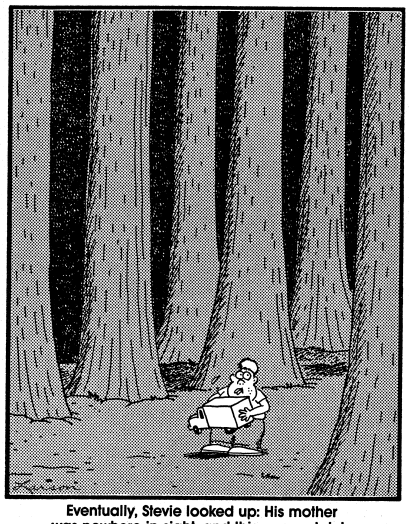
A Traditional Model for Decision Making



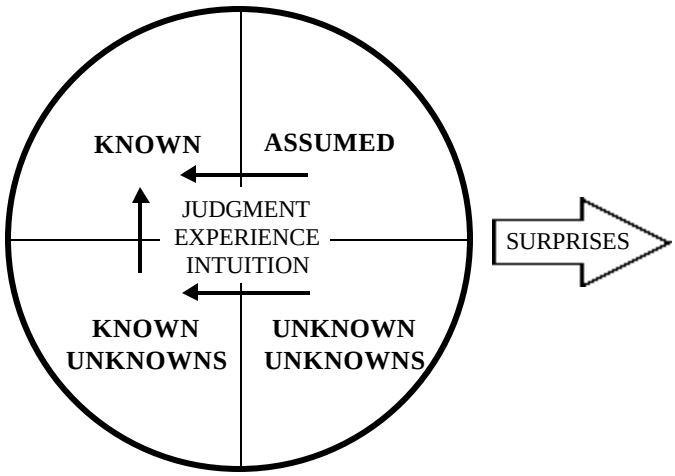
Building Knowledge from Information: Perception of the Situation



When We Correlate the Available Information We May Find That
We Now Know Something, But We May Not Understand It



The Perception Map



Mistakes and Surprises

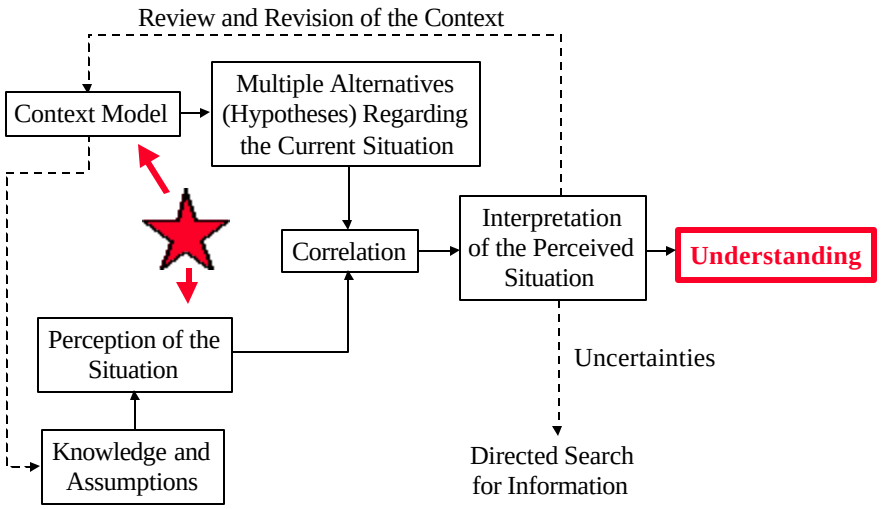
- Our Knowledge Is Never Perfect
  - We Cannot Know "Ground Truth" Except in Cases Where We Ourselves Define the Situation (i.e. In Exercises)
- We Often Forget That Some of Our "Knowledge" Was Really Based on Assumption
  - The Best Form of Deception Is to Show the Enemy Something That He or She Expects to See
- Unknown Unknowns Are the Big Villains
  - We Must Continually Test the Environment to Make Sure That the Observed Information Does Not Contain Important Departures From Our Perception Model
- All Knowledge Is Really Statistical in Nature
  - Confidence Level Must Be Understood

Understanding Is the Basis for the Decision

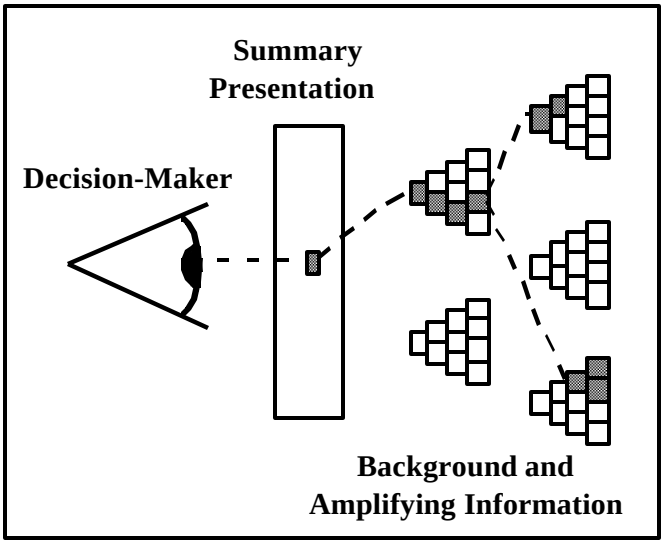
"I Don't Understand Everything I Know."

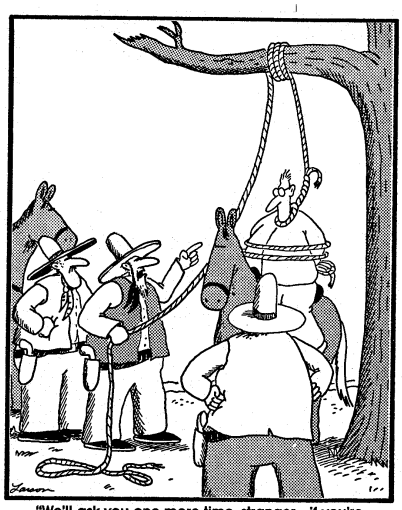
- This Statement Provides the Best Insight Into the Difference Between Knowledge and Understanding
- Information Systems Need to Help the Decision-Maker Understand the Situation, Not Just Know It
  - Situation Awareness Is Not the Objective
  - Situation Understanding Is Our Goal
- If I Know Too Much, It May Impede My Understanding of the Critical Information -- Information Overload, "Glare of War"
- If I Know Too Little, My Predisposition to Assume Things May Distort My Perception of Reality
  - Experts Have Greater Predisposition to Assume Than Novices
  - The Judgment and Wisdom That Comes With Expertise Also Brings Intellectual "Baggage"

Building Understanding from Knowledge



You Often Need to Be Able to "Drill Down" to View Underlying Information



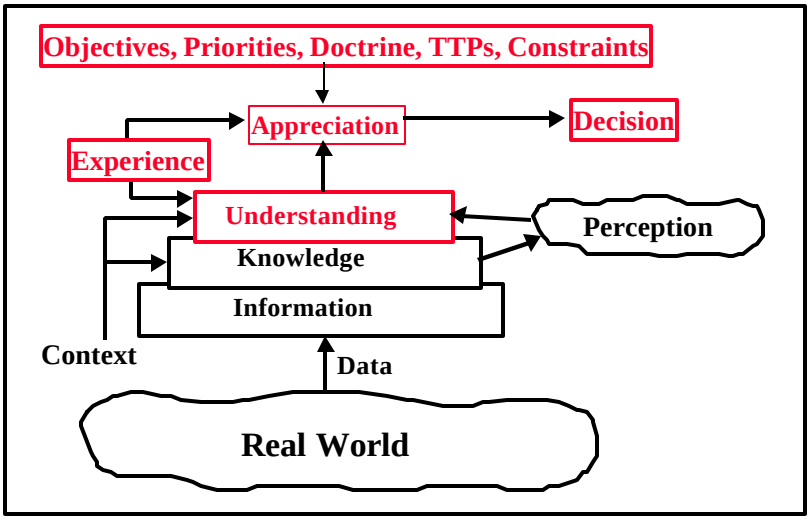


"We'll ask you one more time, stranger—if you're *really* a cowboy from the Rio Grande, then why ain't your legs bowed or your cheeks tan?"

Appreciation: A Higher Form of Reasoning

- Knowledge
  - Matching Available Information to Known Entities and Behaviors in the Real World
- Understanding
  - Matching the Knowledge With One or More Likely States Based on the Context of the Problem
- Appreciation
  - Interpreting the Currently Understood Situation in Terms of the Desired End States
  - Choosing the Response That Best Meets the Objective

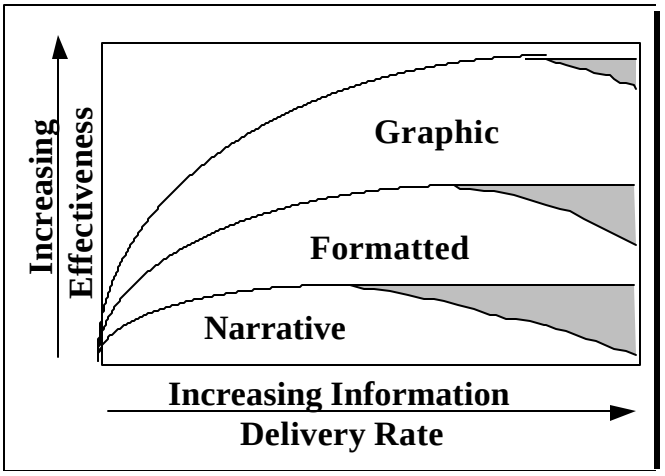
A New View of the Decision Process



Information Systems Need to Be Structured to Support Time-Critical Decision Making in Stressful Situations

- Oriented on Understanding and Appreciation, Not Just Information and Knowledge
- Tailored by the User to Match His or Her Cognitive Processes and Preferences - Not Fixed to a Process Determined by the Engineers and Software Developers
- User-Friendly, Intuitive Human-System Interface
- Integrate Information in the Presentations Rather Than Requiring the User to Integrate in His or Her Head
- Advise on the Impact of Assumptions and Known Unknowns
- Alert the User to Emergent Data That Indicate Errors in Assumption or the Likely Influence of Unknown Unknowns

Impact of Presentation Form



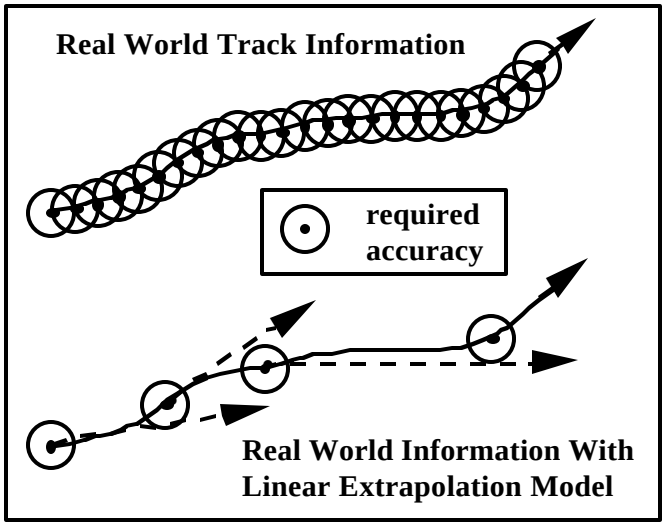
Impact of the System Interaction Method

- The Best Human-system Interface Combines the Interactions With the Normal Process of Doing the Task
- Typing Is One of the Worst Forms
- WIMP - Windows, Icons, Mouse, Point-and-Click Is Better
- Embedding the Interaction Mechanism in the Task Material (E.G. An Active Situation Map or Display) Is Even Better
- Modern Systems Attempt to Offer a Human-system Interface That Is a “Metaphor” of the Workspace
  - The Desktop
  - File Cabinets
  - The Map
  - The Whiteboard

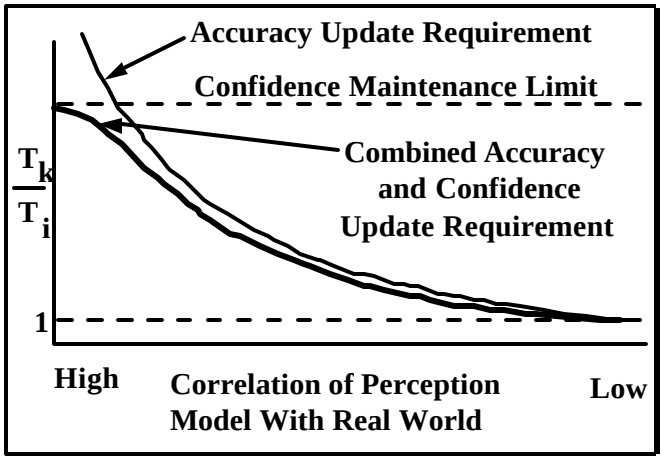
The Power of Knowledge-Based Information Management and Dissemination

- If We All Share the Same Method for Projecting the Situation (Dead Reckoning or Extrapolation) We Only Need to Advise on Unacceptable Departures From the Common Inferred Perception
  - "Significant Delta" Messaging
- Significant Reduction in Communications Throughput
  - Potential for Very Large "Knowledge Gain" Per Transmitted Bit
  - A Means to Reduce Communications Overload
- The Reduction in Human Workload to "Service" the Received Information Can Be Even More Significant
  - Potential for Very Large "Knowledge Gain" Per Display Update
  - A Means to Reduce Information Overload
- Ability to "Self-Synchronize" Decisions and Actions Across a Distributed Command Center or Force

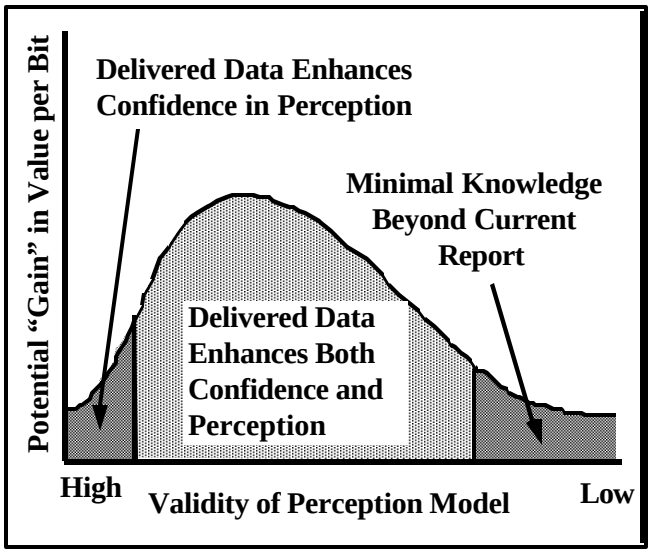
Knowledge-Oriented Information Updates



Potential to Throttle Back on Information Delivery Based on Ability to Infer Knowledge



Gain in Knowledge Value per Delivered Bit



Information-Leveraged Warfare Presents New Challenges as Well as Opportunities

- The "Fog of War": A Continuing Challenge
  - Uncertainty: Let's Not Fool Ourselves - We Are Not Omniscient!
  - Ambiguity: More Information May Increase Ambiguity
  - Assumptions: Forever Necessary to Fill Critical Information Gaps
  - Unknown Unknowns
- The "Glare of War": The New Challenge
  - Massive Inputs of Information
  - Mix of Relevant and Marginally Useful Information
  - Heterogeneous Forms of Information and Presentation
  - Hiding of Important Information Within the "Clutter"

Too Much Information Can Be As Bad As Too Little. The Key Is In The Management And Presentation.

Automated Tools Can Be Applied to Help Deal With a Rich Information Environment

- Knowledge Support
  - Correlators and Fusion Engines
  - Multi-Hypothesis Trackers
  - Uncertainty Displays and Cues
  - Alerting and Reporting Agents
- Understanding Support
  - Multi-Hypothesis Trackers
  - Uncertainty Displays and Cues
  - Visualization
  - Alerting and Reporting Agents
- Appreciation Support
  - Case-Based and Constraint-Based Reasoning
  - Simulation

Applying IT Tools to Achieve the Objective of Information-Leveraged Warfare

- The Vision and Long Term Objective
- Navigating Toward the Objective
- Current Status and Directions
- Challenges

The Long Term Vision

- Joint Vision 2010
  - Orders of Magnitude Increase in Effectiveness Through Information Superiority
- Network-Centric Warfare
  - Increased Operational and Tactical Effectiveness Through the Use of a Distributed Information Network to Allow Us to Move From Sequential Processes to Highly Parallel Processes
  - Modeled After the Successful Applications of Information Technology in the Commercial World
- The Revolution in Military Affairs (RMA)
  - Do Better by Changing the Operational Concepts, Doctrine and Procedures to Take Advantage of New Technology

What Has Changed?

- World War II
  - Emergence of Scheme of Maneuver and Scheme of Fires As Integral Elements of Modern Warfare
  - Information Dominance Largely "in the Black"
- The Cold War
  - Emergence of Information Dominance As an Explicit Adjunct to Maneuver Warfare
- The Post-cold War RMA
  - Information Superiority As a Major Element Added to Maneuver Warfare
  - Scheme of Information Will Emerge As the "Third Leg of the Stool" to Complement Maneuver and Fires*

*Personal Prediction

Caution: It Is Easier to Draw the Vugraph Than to Build the Capability

- The Realities of the Operational Environment
  - Tactical Networks Are Not Like the Internet
  - Demands Are Highest and Most Critical When Systems Are Probably Most Degraded
- Differences Between Commercial and Military Enterprises
  - Commercial Users Live With Their Mistakes
  - Military Users Die With Theirs
  - Commercial Enterprises Recapitalize on a Business Case Basis
  - Military Enterprises Live With Legacy Systems and Recapitalize Only When Congress and DOD Permit
  - Commercial Enterprises Can Usually Choose Their Battlefields
  - Military Enterprises Do Not Have This Luxury

Moving Toward the Vision

- The Mistake of Trying to Design "The Objective System"
  - We Cannot Know the Proper System for 2010 in the Year 2000
  - Technology Changes, Requirements Change, Concepts Change
  - By the Time You Build It, It Will Be the Wrong System
- A Better Approach: Use the Vision to Define the Long Term Objective But Build Incrementally in the "Direction of the Vision"
  - The Problem Is Much the Same As a Navigation Problem
  - Know Where You Are and Where You Think You Want to Go
  - Define Waypoints and Allow Course Changes Along the Way
  - The Key Is to Be Adaptable in the Approach Yet Relatively Consistent in the Objective

Architecture is a Key Element in the Plan

- Operational (Functional) Architecture
  - The Delineation of Functions to Be Performed and the Organizations Responsible for Those Functions
  - The Delineation of the Interactions Among the Functions and Organizations
- Technical Architecture
  - The "Building Codes" for the System
  - Specific Standards, Protocols, Etc. That Must Be Used
- System Architecture
  - The "Plans for the Building"
  - The Physical (Hardware, Software) Implementation

The Changing Relationship Between Human and Machine Is Another Key Element

- Manual Process
  - People Do the Work Using Pencil, Paper, Telephone, etc.
- Computer-Aided Manual Process
  - Humans Use the Technology to Do the Bookkeeping and the Mathematics and to Move the Information Among Themselves
- Automated Process
  - Computers Run the Show
- Human-supervised Automated Process
  - Computers Run the Show, but Humans Can Monitor and Intervene Directly in the Process
- Human-in-the-Loop Process
  - The Human Is Inserted As a "Functional Module" Within the Automated Process
- "Mixed Initiative" Process
  - The Human and the Computer Do Interconnected Tasks

An Important Architectural Issue: "Stovepipes" Versus Commonality

- A Trade-Off Between Objectives That Are Often Competing
  - Tailored, Optimized Performance (e.g. For Weapons Control)
    - Real-Time
    - Strongly Focused on a Specific Function
  - General Purpose, Common Systems and Applications
    - Economy of Scale for Procurement and O&M Support
    - Assured Interoperability
- One Size Does Not Necessarily Fit All
  - Administrative Functions
  - Strategic Command
  - Operational and Tactical Command
  - Tactical Control/Combat Direction
  - Combat Systems and Weapons Systems

Varying Demands Associated with Level of Command or Type of Function

- National and Theater
  - Non-Real Time Decisions Focused at Least Three Days Into the Future
  - Emphasis on Management of ROE, Guidance, & Theater Resources
  - Broadly Focused on a Wide Range of Decision Types
- Joint Task Force
  - Near Real Time Decisions Focused One or Two Days Into the Future
  - Emphasis on Coordination of Actions Across the Force
  - Broadly Focused on a Wide Range of Decision Types
- Warfare Area C2
  - Near Real Time Decisions for Minute-by-Minute Problems
  - Emphasis Within Well Defined Functional Domain
- Platform
  - Real Time Decisions
  - Focus on Maneuver and Fires As Assigned
- Weapon and Sensor Control
  - Real Time Decisions
  - Highly Focused and Tailored for Performance

A Sample Reference Model

Human-System Interfaces
Mission Applications
Mission-Tailored Services
Interoperability (Mediation, Middleware) Services: Translators, Brokers, Protocol Converters, etc.
Common Applications: Mapping, Spreadsheets, Graphics, etc.
Common Information Services: Database Management, Comms Management, etc.
Infrastructure: Hardware and Software

The Current Approach to Building Systems

- National, Theater, and Joint Task Force Perspective
  - A Common Joint System (GCCS, GCSS, DII)
- Tactical Battle Command Perspective
  - Extension of DII for Tactical Command Support
  - Consistent Tactical Picture Via Tactical Data Networks
- Tactical Platform Perspective
  - Combat Systems Custom Tailored to Each Platform
- Horizontal and Vertical Functional Coordination
  - Some Interoperability Through Data Link Standards
  - Many Stovepipes at the Tactical Levels

Joint Technical Architecture

- Definition of Standards That Must Be Applied
- Strongly Oriented Toward Use of Commercial Information Technology Standards
- Sufficiently Flexible to Yield Fully-Compliant Systems That Are Not Necessarily Interoperable
- Not Oriented Toward Real Time Weapons Control or Platform Control Functions

A Word About Interoperability

What Does It Really Mean?

- Technical Interoperability
  - The Hardware and Software Can Operate Together
- Transaction Interoperability
  - Information Can Be Exchanged and Processed
  - Protocols Are Consistent Across the Systems
- Application Interoperability
  - The Applications Can Exchange Information
- Semantic Interoperability
  - Language and Meaning Are Commonly Understood
- Response Interoperability
  - The Expected Responses to Information Are Understood by All
  - e.g. We've Heard the Joke About: "Secure the Building"

Defense Information Infrastructure

- Product Oriented
  - Specific Hardware and Software Approved for Use
  - Emphasis on Common Core Infrastructure and Services
  - Users Can Assemble Specific Functional Variants From Approved Components
- Current Focus Has Been Largely on the Strategic and Operational Levels of Command
  - Genesis From WWMCCS and JOTS (JMCIS)
  - Other C2 Functions Added by DOD Mandate
- Can Achieve Some Degree of Cost-Effectiveness Improvement Through Commonality
- Reasonable Degree of Interoperability for Information Management at the Strategic and Operational Levels
- Intended to Push Down Into the Tactical Domains

Tactical C2 Support Systems

- Combat Direction Systems
  - Example: Navy Tactical Data System (NTDS)
  - Generally Used to Support Coordinated Battle Command Across Multiple Warfare Areas (Battlefield Functional Areas)
  - Extend From Force (JTF, MAGTF, BG/BF, Etc.) To Platforms
  - Usually Standardized Within a Component of the Force but Often Not Force-Wide
  - Should Become JTA Compliant; Maybe DII COE Compliant
- Combat Systems
  - Example: AEGIS Combat System
  - Generally Used to Coordinate and Control the Weapon and Sensor Systems Onboard a Platform
  - Usually Tailored to Platform Types
  - Standardization Is Often an Issue: Performance Vs. Commonality

IT Tools That Are Being Applied

- Translators, Mediators, and Brokers
- Information Search Engines
- Knowledge Integration Tools
- Multi-Hypothesis Trackers
- Automated Reasoning Support Tools
- Software Agents to Track, Alert, and Cue

Translators, Mediators, and Brokers

- Translators
  - Provide Conversion Across Different Languages or Formatting Schemes That Represent the Same Information
  - Sometimes Provide Semantic Reconciliation
- Mediators
  - Provide Semantic Interpretation
  - Provide Some Ability to Merge Information From Multiple Source Databases
- Brokers
  - Provide Access to Appropriate Sources of Information And/Or Processing
  - Facilitate Connecting the Requester With the Provider

Information Search Engines

- Meaning-Oriented Retrieval of Information From Diverse Sources
  - Basic Search Engines Are Word-Oriented
  - Advanced Search Engines May Map the Information Need to the Semantics and Structure of Each Information Source
- Artificial Intelligence Applications May Provide Some Ability to Infer Information Needs Based on Past and Current Human-system Interactions
  - Example: If You Asked for These Two Items of Information, You Probably Also Need This Third One
- Ability to “Mine Data” from a large number of diverse sources is a major emphasis in current information technology

Knowledge Integration Tools

- Correlation
  - Generally Used to Combine Multiple Observations of the Same Event or Entity When the Data Can Be Expressed in Mathematically Precise, Statistical Terms
  - Useful for Combining Measurements Involving Single or Multiple Phenomenologies (E.G. Radar, Sonar, ESM, …)
  - Often Near-Real Time
- Fusion
  - Generally Refers to Combining Information of Very Different Types, Such As Sensor Data, Imagery, or Human Reports
  - Often Non-Real Time
- Semantic Integration
  - Integration of Information Where the Individual Meanings and Relationships Can Infer Larger Meaning
  - Some Degree of Contextual Reasoning May Be Used

Multi-Hypothesis Trackers

- Used to Keep Track of Incomplete Information That Could Indicate Several Likely Situations
  - Each Potential Situation Is One "Hypothesis"
  - Data Collection Continues in the Hope That One of These Can Be Determined to Be the Most Likely
- Applies Mathematical Formalism for Statistical Interpretation of Observations
  - Maximum Likelihood Estimation (e.g. Kalman Filters)
- MHTs Are Core Components of Most Correlation and Fusion Engines

Automated Reasoning Support Tools

- Situation Assessment
  - Correlation, Fusion, MHTs As Previously Discussed
  - Bayesian Nets, Neural Nets and Other Diagnostic Tools
  - Advanced Tools for Inferring the Situation From Incomplete and Ambiguous Information
    - e.g. Dempster-Shafer Estimation of Likelihood
    - "Expert System" Pattern Recognition and Inference
- Course of Action Planning
  - Case-based Reasoning
  - Generative Planning
  - Mixed-initiative Planning

Software Agents to Track, Alert, and Cue

- An "Intelligent Agent" Is a Piece of Software That Can Operate Autonomously to Execute a Task
- One of the Most Powerful Use of Intelligent Agents Is to Keep Track of Important Observations
  - To Resolve Uncertainty
  - To Notify Operators When Some Critical Entity or Event Is Observed
  - To Reduce the Need for the Humans to Keep Track of Massive Amounts of Information
- Simple "Intelligent Agents" Can Be Tasked to Look for Specific Information or Patterns of Information
  - To Help Move From "Known Unknown" to "Known"
  - To Help Move From "Assumed" to "Known"
  - To Alert to Previously "Unknown Unknowns"

Some Obstacles to Be Overcome

- Lack of Interoperability Among Legacy Systems
  - Being Addressed With the JTA, DII COE and Digitization Efforts Within the Services and DOD
- The "Tug of War" Between Requirements for Focused Performance Versus Commonality
  - Probably the Most Difficult Issue
- Diverse Cultures and Perspectives
  - Pervasive Influence on Force Structure, System Architecture, Semantics, Functional Processes
- The Rapid Pace of Technology Advancement
  - The System That We Design Today Will Be Obsolete by the Time It Is Fielded
- Costs
  - How to Build a "Business Case" for IT Investments?